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Pacific Environmental Services, Inc,

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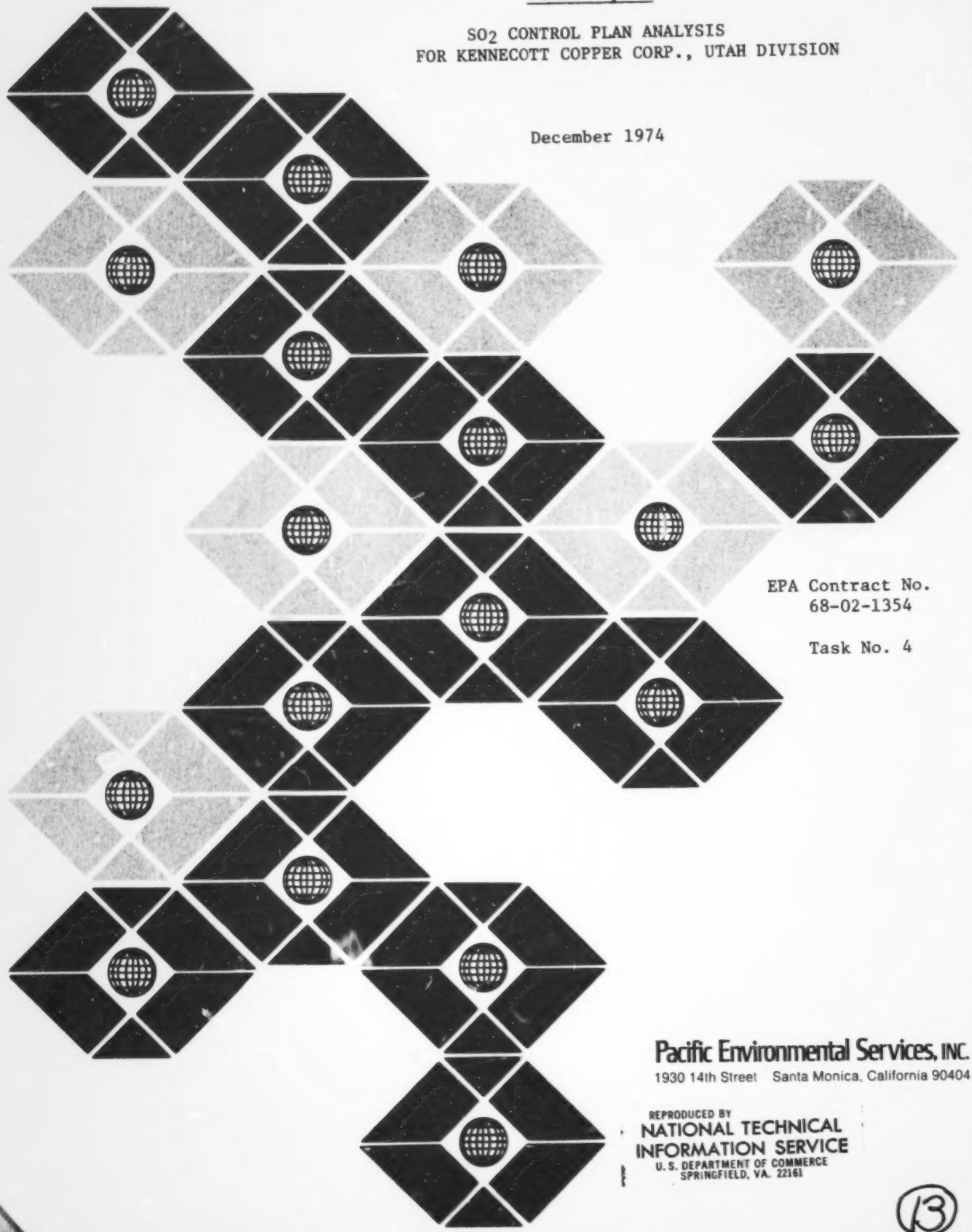
Final Report

SO_2 CONTROL PLAN ANALYSIS FOR KENNECOTT COPPER CORP., UTAH DIVISION

December 1974



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Final Report

SO_2 CONTROL PLAN ANALYSIS FOR KENNECOTT COPPER CORPORATION, UTAH DIVISION

December 1974

by

I. J. WEISENBERG
PES Environmental Engineering Dept.
A. Stein, Director

EPA CONTRACT NO. 68-02-1354 -- TASK 4

Project Officer: NORMAN HUEY, Chief Control Technology Section Air & Water Programs Division Environmental Protection Agency Denver, Colorado

PACIFIC ENVIRONMENTAL SERVICES, INC.
1930 - 14th Street
Santa Monica, California 90404

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I. BACKGROUND AND SUMMARY

The Kennecott Copper Corporation, Utah Copper Division has proposed modifications and additions to their existing acid plant complex to meet current and future SO_2 regulatory requirements. This report presents a technical review of these plans and of potential upgrading approaches.

The current Kennecott plan includes replacing the present reverberatory furnaces with Noranda reactors using oxygen enrichment for smelting green charge to 70% copper matte, which will then be converted to blister copper in conventional Peirce-Smith converters. It is expected that total offgases from the new process will contain 7% to 10% SO_2 and should be readily adaptable as feed for sulfuric acid manufacture.

Acid Plants 3 and 4 will be retired from service. Acid plants 5, 6 and 7 will be upgraded to receive the new richer feed stream and a new plant No. 8 will be constructed. Because current operations average 4% SO_2 stream to the acid plant, it is claimed by Kennecott that efficiencies will be low for upgraded plants 5, 6 and 7 (all single-contact). Kennecott also plans to make the new No. 8 plant a single-contact.

Counting captured fugitive emissions, the Kennecott plan will not meet the requirements of Utah implementation plan 40 CFR Part 52 (Federal Register Vol. 39, No. 203-58, October 18, 1974). Four major approaches to SO_2 control for this plant have been considered and are presented in this report with additional modifications totaling twelve possibilities. Of these twelve, seven will meet the implementation plan requirements at an estimated additional cost in the 2% to 3% range of present planned expenditures.

II. APPROACHES AND ALTERNATIVES

Four major approaches to SO_2 control for the Kennecott Utah copper smelter have been analyzed with additional modifications totaling twelve possibilities. Of these, at least seven fall within the allowable value. The four major approaches are:

1) Present Kennecott Plan
2) Change new plant No. 8 to double-contact
3) Reduce acid production with no change to present plants, and increase size of new plant No. 8.
4) Combine old plants and convert to double-contact.

Additional modifications include variation of efficiencies (including use of double-contact system), partial changes to present plan, reduction of flow rates, and reduction of acid production.

Calculations were made covering SO_2 emissions in lbs/hr for plants Number 5, 6, 7 and 8. These results can be compared to the 5400 lbs/hr called for in the Utah Implementation Plan 40 CFR Part 52, issue in the Federal Register Vol. 39, No. 203-58 (October 18, 1974). A deduction of 1,766 lbs/hr is made to account for captured fugitive emissions, leaving allowable 3,634 lbs/hr that can be emitted from acid plants 5, 6, 7 and 8.

The Kennecott letter summary dated October 8, 1974 indicates that at their present planned estimated acid plant efficiencies, a total of 8,517 lbs/hr will be emitted. This is divided as follows:

Acid Plant	SO_2 lbs/hr Out
5	1750
6	2350

Acid Plant	SO_2 lbs/hr Out
7	2617
8	1800

PES has calculated acid plant performance based on Kennecott sulfur input, volume flow rates, and assumed efficiencies as listed below:

Acid Plant	Volume SCFM	Sulfur TPD	SO_2 TPD	SO_2 #/hr	SO_2 SCFM	SO_2 %(b.v.)	Plant Efficiency %	SO_2 Emissions #/hr	100% H_2SO_4 100%Eff
5	29100	149.7	299.4	24960	2330	8.0	93.0	1747	452.3
6	61000	313.9	627.8	52320	4883	8.0	95.5	2354	961.3
7	61000	313.9	627.8	52320	4883	8.0	95.0	2616	961.3
8	83600	430.2	860.4	71700	6692	8.0	97.5	1793	1317.5
TOTALS	234700			201300				8510	3692.4

The following discusses the alternate approaches shown in Table I:

Alternative 1 is the present Kennecott approach, using efficiencies shown in the above table.

Alternative 2 assumes 97% efficiency for all plants. This approach would require increasing the catalyst in the existing converter and adding another converter to reach the point where more "normal" single-contact acid plant efficiency could be obtained. Usual guaranteed single-contact efficiency is 97.5% for a new plant (See Section IIIA2).

Alternative 3 provides Plant 8 as a double-contact plant operating at 99.5% efficiency (guaranteed for new plants - some actual plants are doing better than this). Plants 5, 6 and 7 will remain as single-contact, but will operate at 97% efficiency. This would, as in approach 2, require additional catalyst for these plants.

Table I. ALTERNATE APPROACHES

APPROACH		Plants 5 thru 8 only: SO_2 emissions (lb/hr)	Estimated Cost
1. Present Kennecott Plan	A	8517	$175,000,000*
2. 97% efficiency on all plants	A	6040	3,000,000
3. DC Plant 8 (99.5%); SC Plants 5, 6, & 7 (97%)	B	4248	5,350,000
4. DC Plant 8 (99.5%); SC Plants 5, 6, & 7 (97.5%)	B	3599	5,350,000
5. Existing plants 97% w/ dilution air to obtain 4% SO_2 & add lgr DC plant to make up difference (double size)	C	3309	14,300,000
6. Reduce vol. flow to plants 5, 6 & 7 to 80% present to obtain 97.5%; increase plant 8 by 36% (from 71, 118 to 97,620 SCFM)	C	3079	4,500,000
7. Same as (6) except DC = 99%, SC = 97%	C	4087	4,500,000
8. Same as (6) except DC = 99.5%, SC = 97%	C	3599	4,500,000
9. Combine plants 6 & 7 for DC (99.5%) w/ plant 5 (93%) & plant 8 (97.5%) same as present plan	D	4063	1,235,000
10. Plant 5 same as present (93%); plants 6 & 7 w/ combined DC (99.5%) & plant 8 DC at 99.0%	D	2987	4,335,000
11. Plant 5 same as present (93%); plants 6 & 7 combined DC (99%); & plant 8 DC at 99%	D	3511	4,335,000
12. Plants 5, 6 & 7 combined DC at 99%; plant 8 DC at 99%	D	2014	5,085,000

*Total cost of present Kennecott plan including new reactors and additional modifications.

Alternative 4: This approach assumes that Plant 8 is a double-contact operating at 99.5% efficiency, and that Plants 5, 6 and 7 are single-contact operating at 97.5% efficiency. This would be the best performance combination, assuming use of the noted single-and double-contact designs with increased catalyst.

Alternative 5: Uses existing plants operating under conditions essentially the same as at present: dilution with air to 4% SO_2, and utilization of the same volume flow rates for 97% efficiency. This requires increasing the size of the new No. 8 plant to approximately twice present planned size (159,146 SCFM instead of 83,600 SCFM) and using the double-contact design, at 99% efficiency. Adding dilution air to existing plant should improve the oxygen to sulfur dioxide ratio, thereby maintaining or increasing current efficiencies.

Alternative 6: As the percent SO_2 is increased in the input stream to an acid plant, efficiency will eventually be reduced from optimum. Since the present plants will receive 8% SO_2 as compared to their present 4% SO_2, it is estimated that the volume flow should be reduced to 80% of the present flow, to obtain 97.5% efficiency. This approach assumes that the volume flow to plants 5, 6 and 7 is reduced to 80%, that the new plant No. 8 is a double-contact (99.5% efficiency) and is increased in capacity by 36% (from 71,118 SCFM to 97,620 SCFM). The other plants remain as single-contact but havé added (extra catalyst) as in the present Kennecott plan.

Alternative 7 is identical with 6, except that the double-contact plant was assumed to have 99% efficiency and the single-contact 97%.

Alternative 8 is equal to 6, except that in the case of plant 8, the double-contact was assumed to be 99.5% efficient because it is a new plant, and the single-contacts are assumed to be 97.0% efficient.

Alternative 9 requires combining plants 6 and 7 to obtain a double-contact 99.5% efficiency, retaining plant 5 at present conditions under the Kennecott plan with 93% efficiency, and having 8 with 97.5% efficiency as a single contract. (See Section III. B.)

Alternative 10: Plant 6 and 7 are combined as a double-contact with

99.5% efficiency, Plant 8 has a double-contact 99.0% efficiency, and Plant 5 remains at present Kennecott plan 93% efficiency.

Alternative 11: Plants 6 and 7 are combined as double-contact 99.0% efficiency, Plant 8 is a double-contact at 99.0% efficiency, and Plant 5 is at its present 93% efficiency.

Alternative 12: Plants 5, 6 and 7 are combined as double-contact at 99% efficiency, with Plant 8 as a double-contact at 99%.

Using the 5400 lbs/hr emission limitation as noted in the October 18 regulation as the basis, and subtracting the 1,766 lbs/hr captured fugitive emissions as noted in the Kennecott October 8 letter, the maximum allowable emissions would be 3,634 lbs/hr. Alternate approaches 4, 5, 6, 8, 10, 11 and 12 can be used to meet the 3,634 lbs/hr limitation.

On a cost effective basis, in terms of SO_2 reduction, approach 12 appears best with 10 and 6 following in that order for those with the capability of meeting the regulation.

III. SPECIAL CONSIDERATIONS

A. FACTORS AFFECTING EFFICIENCY

1. Oxygen to Sulfur Dioxide Ratio

Kennecott has indicated that the offgases from the Noranda reactor will contain a considerable amount of oxygen because of the oxygen addition. The following Table II summarizes the variation of SO_2, oxygen, and oxygen-to-SO_2 ratio.

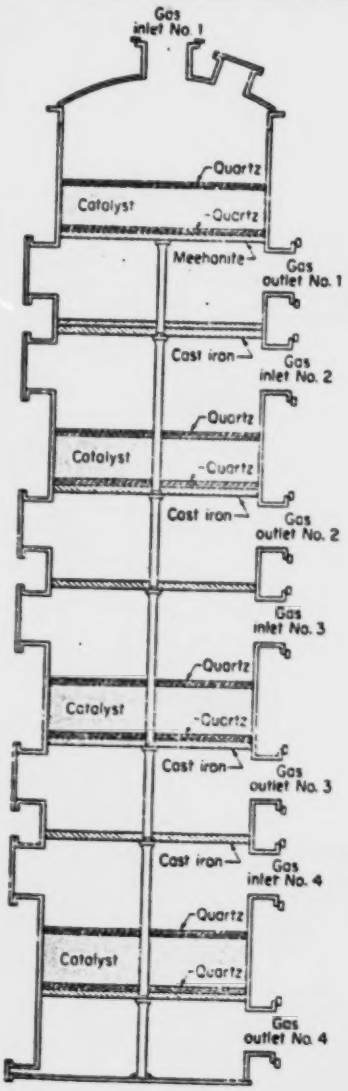
Table II. NORANDA REACTOR OFFGAS

Noranda	Offgas	
% SO_2	% O_2	O_2/SO_2
7	14	2.0
8	13	1.625
9	12	1.335
10	12.25	1.225

The oxygen-to-SO_2 ratio is important from the conversion efficiency standpoint (optimum ratio is 1.35 - 1.4). As can be seen from the above table, oxygen enrichment provides a very favorable oxygen-to-SO_2 ratio and should promote high efficiencies for the conversion of SO_2 to SO_3.

2. Catalyst Bed Loading

The converter for Plant 6 has a 33-ft diameter and a total height of 37 ft, and contains 101,400 liters in four beds. The total volume of the 101,400 liter catalyst is 3,582 cu. ft, while the converter's total volume is 31,630 cu. ft. Part of the reason for the large volume is to allow removal of the catalyst for cleaning (screening). Bed thicknesses generally are 12 to 18 in. Figure 1 shows a typical converter arrangement. Some of the beds--particularly the first--lend themselves to additions. Also some designers eliminate the top layer of quartz which could be replaced with additional catalyst.



Monsanto four-pass converter. In plants in which cold SO_2 gas must be heated by means of heat in the SO_3 gas, each of the four gas outlets except No. 3 is connected to a tubular heat exchanger. Each of the gas inlets except No. 4 is for the return connection from the exchanger. Gas outlet No. 3 and inlet No. 4 are connected to a small flue cooler from which the heat is discarded because it is insignificant in amount and not needed for preheating SO_2 gas. In sulfur-burning plants, many variations are used for SO_3 gas cooling. Any of the gas outlets may be connected to a heat exchanger, waste-heat boiler, steam superheater, economizer, or other cooling equipment. Also, any of them may be used for injection of cold, dry air (*Monsanto Chemical Co.*)

REFERENCE: Chemical Process Industries. R.N. Shreve, 1967.

Figure 1. TYPICAL CONVERTER

Inlet and outlet ducting can minimize available volume for increasing catalyst content as well as available blower static pressure capability.

Plant 7 has 89,500 liters of catalyst in four beds, and is estimated to be 34 to 35 ft. in diameter and 45 to 46 ft. high, with dimensions similar to Plant 6.

Plant 5 has a 25 to 26 ft. diameter converter, with approximately 42,000 liters of catalyst.

Distribution of the catalyst is generally as follows:

CATALYST BED APPORTIONMENT

1	18%
2	22%
3	26-28%
Last Remainder	

Converter catalyst loading will be increased to as much as the existing converters will handle. The following table summarizes catalyst quantities in the existing and upgraded plants as presently planned by Kennecott.

PLANT NUMBER	PRESENT CATALYST LITERS	CATALYST ADD FOR UPGRADE LITERS	CATALYST NEW TOTAL LITERS
5	42,000	21,470 (estimate)	63,470
6	101,400	35,520	136,920
7	89,500	50,340	139,840

The rule of thumb for catalyst bed loading for maximum efficiency for long periods is generally 180 liters/TPD of acid for either single or double contact plants. This would indicate the following catalyst volume requirements for the new operating conditions. (See Page II-2).

ACID PLANT	H_2SO_4 TPD	CATALYST REQUIRED LITERS	UPGRADED CATALYST AS % REQUIRED
5	452.3	81,414	78
6	961.3	173,034	79
7	961.3	173,034	81
8	1,317.5	237,150	

This would imply that if the SO_2 feed to the upgraded plants is reduced to 80% of planned, then maximum efficiencies (97.5% S.C.) could be obtained. This is considered for Alternate 6. It should be noted that as SO_2 concentration increases, catalyst requirements are increased to meet the loading criteria.

B. COMBINING PLANTS 6 AND 7 TO FORM A DOUBLE-CONTACT SYSTEM

Plants 6 and 7 are the same size and produce the same amount of acid on a daily basis. They could be combined to form one large double-contact plant, to which it would be necessary to add one large absorption tower.

The plants would be operated in parallel through to the second or third bed of each converter; then, the partially converted SO_2 stream would be pulled off and sent to the existing absorption towers.

From the existing absorption towers, the gas would be brought back to the existing converters, to pass through the remaining beds. The gases would then be brought from the existing converters, combined, and sent to a single absorption tower to absorb the remaining SO_3. From this single large tower, the gases would be split and brought back to the present system for completion of the process.

A new single absorption tower would be required to handle the total flow from each plant or, if room does not permit, two absorption towers could be provided to allow location in the most advantageous area.

C. RELIABILITY OF DOUBLE VS. SINGLE-CONTACT PLANT

When considering reliability of an acid plant used in conjunction with a smelter, the availability time is the prime consideration. In the newest plants installed at smelters, it is current practice to parallel systems starting at the gas conditioning end. Thus, one acid plant consists of two complete plants, each of half capacity.

The major operating advantage of this arrangement is to allow shutdown of one side for repairs if required, with operation of the other side at somewhat higher than design capacity for short periods. With normal fluctuation of smelter output (particularly from the converters) it is possible to control a significant portion of the SO_2 emissions.

The additional equipment which must be added to change from a single-contact to double-contact (converter, absorption tower, heat exchangers, ductwork, piping) would seem to introduce a reduction in reliability. If overall plant reliability were considered on the basis of a series of components, all of which had to work, then the individual part reliability would be multiplied together and would result in a low number. This however is not the actual case in either single- or double-contact systems.

Operation can be continued when many components in the plant are not working properly. Also, the maintenance of continuous operation (keeping the system hot) will improve reliability of all equipment far greater than any possible reduction due to an increased number of components. Most of these contain non-moving structures with little that can go wrong except plugging. Kennecott is properly planning on operating the total acid plant complex so that all plants will remain hot as much as possible. Each plant's production will be reduced proportionately when sufficient SO_2 is not present, rather than shutting down one and maintaining full production on the other plants.

IV. COST

During the last several years, costs for major capital equipment have been increasing continuously. Today acid plant vendors will provide fixed price estimates for engineering and include escalation clauses for construction and equipment.

As an example, one vender indicated that in the fall of 1972, a price of $9,000,000 (battery limits) was quoted for two 1800 TPD acid plants. In November 1974 the quotation for the same size plant was $9,000,000 for one.

Changing a new plant design from single-contact to double-contact in the 1000 to 2000 TPD range will add approximately 15%. To convert an existing plant to double-contact would require approximately $2,000,000. For revamp work, the contract would usually be cost-plus-fixed-fee for engineering and construction.

Scale up factor for acid plants is generally considered as 0.6 Thus, the cost multiplier K, is determined as

$$K = \left(\frac{\text{new plant size}}{\text{old plant size}}\right)^{0.6}$$

and the new plant cost = K (old plant cost)

The gas cleaning section costs for metallurgical gases will vary between 1.1 and 1.5 times acid plant cost. 1.3 was assumed as representative for this study.

The curve (Figure 2) shows acid plant costs versus size in tons per day. As SO_2 concentration increases, costs per TPD are reduced essentially in direct proportion.

Estimated additional costs for the twelve approaches are shown in Table 1.

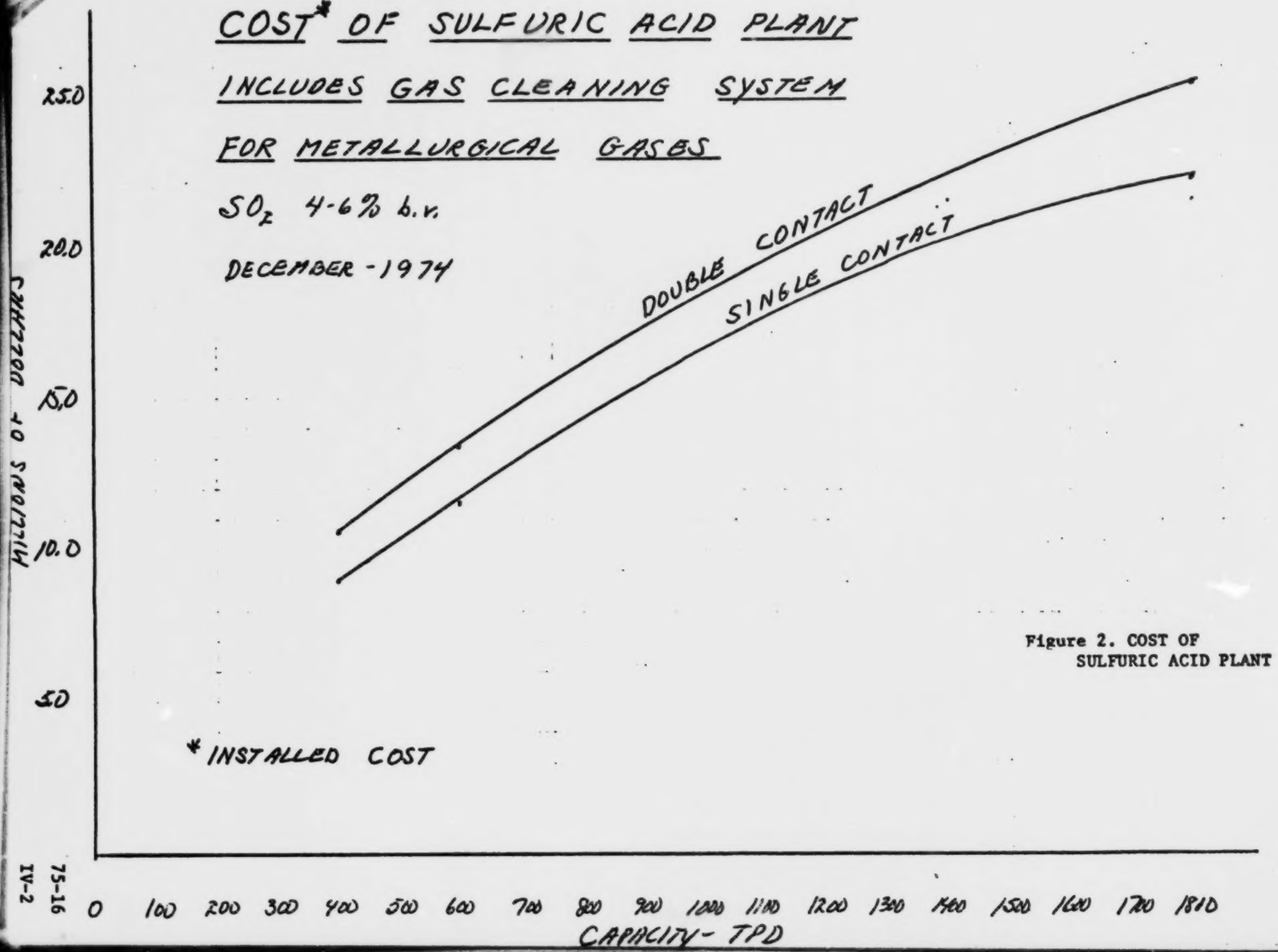


Figure 2. COST OF SULFURIC ACID PLANT

V. MEETING WITH KENNECOTT COPPER CORP., UTAH COPPER DIVISION, SALT LAKE CITY, UTAH TO REVIEW ACID PLANT PLANS.

A meeting was held with the Kennecott Copper Corporation at the smelter in Salt Lake City on October 31, 1974 to discuss Kennecott's acid plant plans and to determine the reasons why their upgraded acid plants were predicted to be only 93% to 95% efficient.

Kennecott

E.D. Butler, Acid Plant Superintendent
D.P. Csanky, Acid Plant Project Engineer
J.L. England, Senior Project Engineer
Dr. R.J. Heaney
Dr. F. Templeton
A.V.J. Prather, General Counsel
H. Monnig, Associate General Counsel

Monsanto Enviro-Chem Systems, Inc.

E. Doyle, Sales Manager
J.R. Donovan, Manager Process Technology

Environmental Protection Agency

I.J. Weisenberg, Senior Environmental Engineer, PES
D.F. Carey, Chemical Engineer, EPA
N. Huey, Region VIII, EPA

While in some plants only the Noranda reactor is used to completely smelt the ore, Kennecott will use an additional converting step. Matte generated from the Noranda reactor will be 70% copper. Two converters will be used to reduce the 70% copper to blister copper.

A total of 219,000 SCFM will be generated by the two reactors and the two converters when all are operating simultaneously. The reactors will be rebricked after 90 days operation. Each Noranda reactor will generate 90,000 SCFM.

A total of 234,000 SCFM (dry) will be the design number for the converted acid plants. Total acid plant capacity is 4,000 TPD. Existing Plant 6 is a Parsons plant; Plants 5 and 7 are Monsanto. Plant 8 will also be Monsanto.

The gas cleaning system in the acid plants will be designed for 11% SO_2. Scrubbers and cooling towers are used. Kennecott expects a 400°F gas entering the acid plants, but will design for 600-650°F.

Cooling temperature is between 75° and 80° in the summer, and the plant's altitude is 4250 feet. Kennecott will be providing new cooling towers and heat exchangers.

Plant 7 will have mist precipitators added. Plants 6 and 7 will receive one humidifying tower and two packed scrubbers.

Five packed cooling towers will also be added. Plant 8 will be the same as Plants 6 and 7.

Kennecott will change acid coolers to shell and tube instead of the Dupont multi small tubes, and will add new Brinks mist eliminators which will add approximately 4 in. w.c. increase in the overall plant pressure drop.

The Plants 6 and 7 will have the mist eliminator mounted on the cooling tower. At Plant 5, the mist eliminator will be located on the ground. Kennecott also has increased acid tank capacity.

The company stated that it is adding as much catalyst as the converters will presently hold, as there is not enough room to add additional converter units. The reason given for not changing to double-contact for the new plant was that it was expected the plant would be down an additional 2% of the time if the additional equipment necessary to make the plant a double-contact system were installed, thus negating the acid production gain.

The plant has problems with brackish cooling water and is going to FRP piping material.

It was noted by Monsanto that when reduced gas volume is going to the plant, the efficiency of the plant should be increased. Since the acid plants are designed to handle the maximum flow rate from both converters and reactors, there will be some period of time when the efficiency will be higher than that quoted.

Plants 3, 4, 5 and 6 use a 3600-RPM direct-connected blower for acid plant operation. Plant 7 uses an 1800-RPM to 4400-RPM speed variable drive for its blower.

During operation of the smelter, when one of the major smelting units is down, an attempt will be made to keep all acid plants in operation to maintain a more steady condition. The SO_2 content will be reduced to 7% by dilution; then, if further reduction is necessary, the gaseous volume flow to each of the plants will be decreased.[1]

The preheater is designed to handle 35 to 40% of the gaseous flow going to the acid plant. This design value was established as the lowest for the blowers without surging.

At the present time, the plant makes 98% acid only in the winter because of its cooling capability. (SO_2-laden gases enter the drying tower at 75 to 95°F.)

Kennecott can ship 93% acid to most of its customers. 98% acid makes up only 3 to 5% of the total quantity shipped.

Present acid plants operate at approximately 97% efficiency.

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[1] The 7% number was selected to insure that operation will always be in the autothermal range.

APPENDIX

CALCULATIONS SUMMARY

Plant #	Volume Flow SCFM	SO_2 #/Hr	Efficiency %	SO_2 Emissions #/Hr.	Comment
			APPROACH # 2		
8	83600	71700	97.0	2151	
5	29100	24960	97.0	749	
6	61000	52320	97.0	1570	
7	61000	52320	97.0	1570	
Total				6040	
			APPROACH #3		
8		71700	99.5	359	
5		24960	97.0	749	
6		52320	97.0	1570	
7		52320	97.0	1570	
Total				4248	
			APPROACH #4		
8		71700	99.5	359	
5		24960	97.5	624	
6		52320	97.5	1308	
7		52320	97.5	1308	
Total				3599	

APPENDIX

CALCULATIONS SUMMARY

Plant #	Volume Flow SCFM	SO_2 #/Hr	Efficiency %	SO_2 Emissions #/Hr.	Comment
			APPROACH #5		
5	29100	12480	97.0	374	
6	61000	26160	97.0	785	
7	61000	26160	97.0	785	
8	159146	136500	99.0	1365	New plant approximately double present plan.
Total				3309	
			APPROACH #6		
8	131020	97620	99.5	488	New plant increased by 36% present plan
5	22480	19968	97.5	499	Reduce volume flow to 80% of present value for maximum efficiency
6	48800	41856	97.5	1046	
7	48800	41856	97.5	1046	
Total				3079	
			APPROACH #7		
8	131020	97620	99.0	976	
5	22480	19968	97.0	599	
6	48800	41856	97.0	1256	
7	48800	41856	97.0	1256	
Total				4087	
			APPROACH #8		
8	131020	97620	99.5	488	
5	22480	19968	97.0	599	
6	48800	41856	97.0	1256	
7	48800	41856	97.0	1256	
Total				3599	

APPENDIX

CALCULATIONS SUMMARY

Plant #	Volume Flow SCFM	SO_2 #/Hr	Efficiency %	SO_2 Emissions #/Hr.	Comment
			APPROACH #9		
8		71700	97.5	179	Plant 8 S.C.
5		24960	93.0	1747	
6		104640	99.5	523	Plants 6 & 7 Combined D.C.
7					
Total				4063	
			APPROACH #10		
8		71700	99.0	717	Plant 8 D.C.
5		24960	93.0	1747	
6		104640	99.5	523	Plants 6 & 7 Combined
7					
Total				2987	
			APPROACH #11		
8		71700	99.0	717	
5		24960	93.0	1747	
6		104640	99.0	1047	
7					
Total				3511	
			APPROACH #12		
8			99.0	717	All plants D.C.
5			99.0	250	
6			99.0	1047	
7					
Total				2014	